

CHARACTERIZATION OF INDIGENOUS MANGO GERMPLASM ADAPTED TO SODIC SOILS OF AYODHYA, UTTAR PRADESH

Rishabh¹, Santosh Kumar Verma¹, Rishant Shukla¹, Satyanshu Singh¹, Atul Yadav¹, Amit Mishra¹, Hemant Kumar¹, Ujjwal Shrivastava², Imran Ali¹, and Jagveer Singh^{1*}

¹ Department of Fruit Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India.

² Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh 208002, India.

*Corresponding author: Jagveer Singh; email: jagveersinghort@gmail.com.

ABSTRACT

Morphological characterization provides an essential first record for locally maintained mango germplasm and future breeding programs. Nine indigenous mango genotypes, designated AMR-1 to AMR-9, were characterized from the salt affected sodic soil in Ayodhya district, Uttar Pradesh, India, during 2023–2025. Crown shape, growth habit, foliage density, leaf blade shape, leaf apex, leaf base, leaf margin and six external fruit characters were scored using the International Plant Genetic Resources Institute mango descriptors. Spreading growth habit occurred in seven genotypes (77.8%); five genotypes (55.6%) had intermediate foliage density and four (44.4%) had dense foliage. Eight genotypes (88.9%) had lanceolate leaf blades, whereas AMR-3 was elliptic. All genotypes had an acuminate leaf apex and acute leaf base, and AMR-9 alone had a wavy margin. Fruit morphology was more variable: elliptic fruit occurred in three genotypes, ovoid and obovoid fruit in two genotypes each, and roundish and oblong fruit in one genotype each. AMR-9 combined an erect tree habit, dense foliage, a wavy leaf margin and an oblong fruit with an acute apex. The descriptor profiles document visible differences among the sampled trees and provide a basis for conservation and further evaluation.

KEYWORDS: crown architecture; fruit shape; germplasm documentation; leaf blade; plant genetic resources; qualitative traits

INTRODUCTION

Mango (*Mangifera indica* L.) is a perennial fruit crop with substantial variation in tree architecture, foliage and fruit characters. This diversity is maintained in named cultivars, seedling-derived trees and locally selected forms, and it is especially visible in regions where old trees have been retained by farmers. Indian germplasm catalogues and evaluations of collections from several geographic origins have documented wide ranges in morphological and fruit-quality traits (Dinesh and Vasugi 2002; Rajan et al. 2013; Zhang et al. 2020; Singh et al. 2025). Local trees can therefore be useful sources of distinctive phenotypes, but their value cannot be assessed reliably unless observations are recorded with a common terminology.

Standardized morphological descriptors provide that terminology. They define discrete states for tree, leaf, inflorescence, fruit and seed characters and specify the developmental stage at which individual characters should be observed (IPGRI 2006). Such descriptors are particularly useful during initial germplasm exploration because they can be applied in the field, permit comparisons among genotypes and help identify material that warrants more intensive biochemical or molecular evaluation. Descriptor-based studies in mango have demonstrated their usefulness for distinguishing genotypes and producing reproducible morphological fingerprints (Kumar et al. 2023). Studies combining morphology with molecular markers have also shown why morphological differentiation should be treated as phenotypic evidence rather than proof of genetic identity (Sennhenn et al. 2014; Kyaing et al. 2019; Liang et al. 2024).

Ayodhya district contains numerous mature mango trees maintained outside formal germplasm repositories, yet many locally recognized trees lack a standardized genotype record. Informal descriptions, photographs taken at different stages and inconsistent use of shape terms can produce contradictory records. A descriptor-based inventory can reduce this ambiguity and create a reproducible baseline for later comparison. The present study therefore aimed to characterize nine indigenous mango genotypes from Ayodhya using standardized qualitative states for tree architecture, mature leaves and external fruit morphology, to identify the traits contributing most to visible differentiation, and to state explicitly the limits of inference from a small, single-district collection. The analysis was deliberately restricted to characters supported by field records and standardized photographs; traits requiring direct measurement, destructive sampling or laboratory analysis were excluded.

MATERIALS AND METHODS

Study area and plant material

Nine locally maintained mango genotypes were documented from salt affected sodic soil with pH > 9.5, EC- 0.44 (dSm⁻¹) and ESP- 35.66% in Ayodhya district, Uttar Pradesh, India, during 2023–2025 and assigned the identifiers AMR-1 to AMR-9. AMR-1, AMR-2 and AMR-3 were located at Biraulijham; AMR-4 at Tindauli; AMR-5 and AMR-9 at Akma; AMR-6 at Bahbarmau; AMR-7 at Itaunja; and AMR-8 at Kumarganj. Geographic coordinates were recorded in the field with a GPS-enabled mobile application and are reported as decimal degrees in the WGS 84 reference system (Table 1).

Each genotype was represented by one mature tree reported to be more than 20 years old. Consequently, the genotype is the sampled tree and the data were taken according to the Descriptors for Mango, developed by International Plant Genetic Resources Institute (IPGRI 2006).

Table 1. Collection localities and recorded geographic coordinates of the AMR mango genotypes.

Genotype	Collection locality	Latitude (degrees N)	Longitude (degrees E)
AMR-1	Biraulijham	26.554598	81.813988
AMR-2	Biraulijham	26.554600	81.813917
AMR-3	Biraulijham	26.551473	81.813357
AMR-4	Tindauli	26.564848	81.795405
AMR-5	Akma	26.552413	81.831524
AMR-6	Bahbarmau	26.546652	81.778878
AMR-7	Itaunja	26.539287	81.810918
AMR-8	Kumarganj	26.543408	81.825347
AMR-9	Akma	26.550481	81.839946

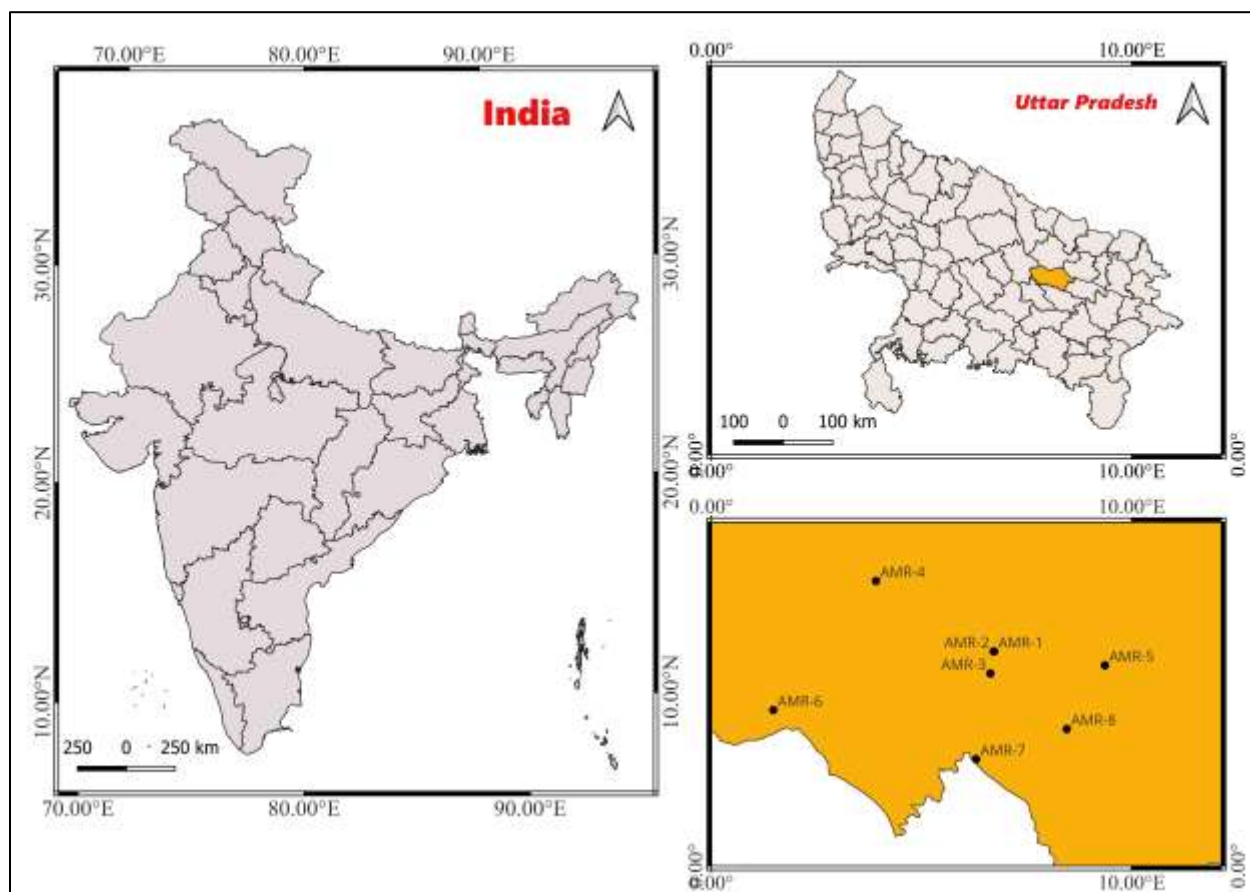


Fig. 1. Geographic distribution of indigenous mango genotypes AMR-1 to AMR-9 evaluated in the present study. The map shows the location of Uttar Pradesh within India, Ayodhya district within Uttar Pradesh, and the individual geo-referenced collection sites of the nine AMR mango genotypes.

Descriptor scoring and photographic documentation

Morphological characterization followed the descriptor states and numerical codes in Descriptors for Mango (IPGRI 2006). Tree descriptors were recorded in situ. Representative field photographs were retained as supporting

documentation, but crown and growth-habit states were assigned from direct observation of the whole tree rather than from a cropped image alone. Crown shape (7.1.6) was scored as oblong (1), broadly pyramidal (2), semi-circular (3), spherical (4) or other (99); growth habit (7.1.7) as erect (1), spreading (2), drooping (3) or other (99); and foliage density (7.1.8) as sparse (3), intermediate (5) or dense (7) (Fig. 2).



Fig. 2. Representative field views of mango genotypes AMR-1 to AMR-9. Tree descriptors in Table 2 were recorded in situ.

Leaf observations were based on 30 fully expanded, mature and visibly healthy leaves per genotype, sampled from different canopy directions and from inner and outer canopy positions. Leaf blade shape (7.2.1) was scored as elliptic (1), oblong (2), ovate (3), obovate (4), lanceolate (5), oblanceolate (6) or other (99). Leaf apex (7.2.9) was scored as obtuse (1), acute (2) or acuminate (3); leaf base (7.2.10) as acute (1), obtuse (2) or round (3); and leaf margin (7.2.11) as entire (1) or wavy (2). One representative mature leaf per genotype was photographed against a uniform background and assembled in genotype order for visual documentation (Fig. 3).

External fruit morphology was assessed on 30 well-developed fruits per genotype. Fruit shape, apex, lenticel density, stalk cavity and neck prominence were recorded at harvest maturity; skin colour was recorded on ripe fruit as required for descriptor 7.4.22. Fruit shape (7.4.7) was scored as oblong (1), elliptic (2), roundish (3), ovoid (4), obovoid (5) or other (99). Fruit apex (7.4.8) was scored as acute (1), obtuse (2), round (3) or other (99). Skin colour of ripe fruit (7.4.22) was scored as green (1), greenish yellow (2), yellow (3), green with red blush (4) or green with purple patches (5). Lenticel density (7.4.13) was classified as sparse (3), medium (5) or dense (7); depth of the fruit stalk cavity (7.4.15) as absent (0), shallow (1), medium (2), deep (3) or very deep (4); and fruit neck prominence (7.4.17) as absent (0), slightly prominent (1), prominent (2) or very prominent (3). One representative fruit per genotype was photographed in a standardized orientation for Fig. 4.

Data analysis

The recorded codes were checked against the allowable states in IPGRI (2006). For each trait, the number of genotypes in each state was counted and expressed as a percentage of the nine genotypes. Percentages were calculated as 100 multiplied by the state count and divided by nine, and were rounded to one decimal place. Genotype differences are therefore reported as observed descriptor combinations.

RESULTS AND DISCUSSION

Tree architecture

The nine genotypes expressed all four named crown-shape states in the descriptor list and one additional state (Table 2). Semi-circular crowns were recorded in AMR-2, AMR-4, AMR-7 and AMR-8 and constituted the largest group

(44.4%). AMR-3 and AMR-9 had oblong crowns (22.2%), AMR-1 was broadly pyramidal (11.1%), AMR-6 was spherical (11.1%), and AMR-5 was assigned code 99 because its observed crown did not fit the four illustrated states (11.1%). Use of code 99 is preferable to forcing an atypical tree into the nearest named class, provided that the observation is described and retained in the genotype record.

Growth habit was less variable than crown shape. Seven genotypes (77.8%) were spreading, whereas AMR-3 and AMR-9 were erect (22.2%). Foliage density was intermediate in AMR-1, AMR-3, AMR-4, AMR-5 and AMR-7 (55.6%) and dense in AMR-2, AMR-6, AMR-8 and AMR-9 (44.4%); no tree was scored as sparse. Crown form, branch orientation and foliage density therefore contributed complementary information. For example, the two erect genotypes shared the same oblong crown state but differed in foliage density, while the four semi-circular genotypes included both intermediate and dense canopies.

Table 2. Tree morphological descriptor states of mango genotypes AMR-1 to AMR-9.

Genotype	Crown shape (7.1.6)	Growth habit (7.1.7)	Foliage density (7.1.8)
AMR-1	2	2	5
AMR-2	3	2	7
AMR-3	1	1	5
AMR-4	3	2	5
AMR-5	99	2	5
AMR-6	4	2	7
AMR-7	3	2	5
AMR-8	3	2	7
AMR-9	1	1	7

Note: Crown shape: 1 = oblong, 2 = broadly pyramidal, 3 = semi-circular, 4 = spherical, 99 = other. Growth habit: 1 = erect, 2 = spreading, 3 = drooping, 99 = other. Foliage density: 3 = sparse, 5 = intermediate, 7 = dense.

Tree architecture can help distinguish genotypes during field exploration, but it is also sensitive to tree age, pruning, storm damage, planting density and competition from nearby vegetation. The AMR trees occurred at different sites and were not managed under a common orchard system. Their architecture should consequently be read as a field phenotype of the documented tree, not as a stable genetic value for a cultivar. Similar caution is necessary when comparing tree descriptors among geographically dispersed mango collections (Rajan et al. 2013; Sennhenn et al. 2014; Zhang et al. 2020). Repeated observations of clonally propagated material in a common environment would be needed to separate genotype effects from management and site effects.

Leaf morphology

Leaf blade shape separated the collection into two groups (Table 3). AMR-3 had an elliptic blade, whereas the other eight genotypes were lanceolate. The lanceolate state was therefore predominant (88.9%), and the elliptic state occurred in 11.1% of the genotypes. The common apex and base states reduced discrimination: all nine genotypes had an acuminate apex and an acute base. Leaf margin provided one additional difference, with an entire margin in eight genotypes and a wavy margin only in AMR-9.

Table 3. Leaf morphological descriptor states of mango genotypes AMR-1 to AMR-9.

Genotype	Leaf blade shape (7.2.1)	Leaf apex (7.2.9)	Leaf base (7.2.10)	Leaf margin (7.2.11)
AMR-1	5	3	1	1
AMR-2	5	3	1	1
AMR-3	1	3	1	1
AMR-4	5	3	1	1
AMR-5	5	3	1	1
AMR-6	5	3	1	1
AMR-7	5	3	1	1
AMR-8	5	3	1	1
AMR-9	5	3	1	2

Note: Leaf blade shape: 1 = elliptic, 2 = oblong, 3 = ovate, 4 = obovate, 5 = lanceolate, 6 = oblanceolate, 99 = other. Leaf apex: 1 = obtuse, 2 = acute, 3 = acuminate. Leaf base: 1 = acute, 2 = obtuse, 3 = round. Leaf margin: 1 = entire, 2 = wavy.

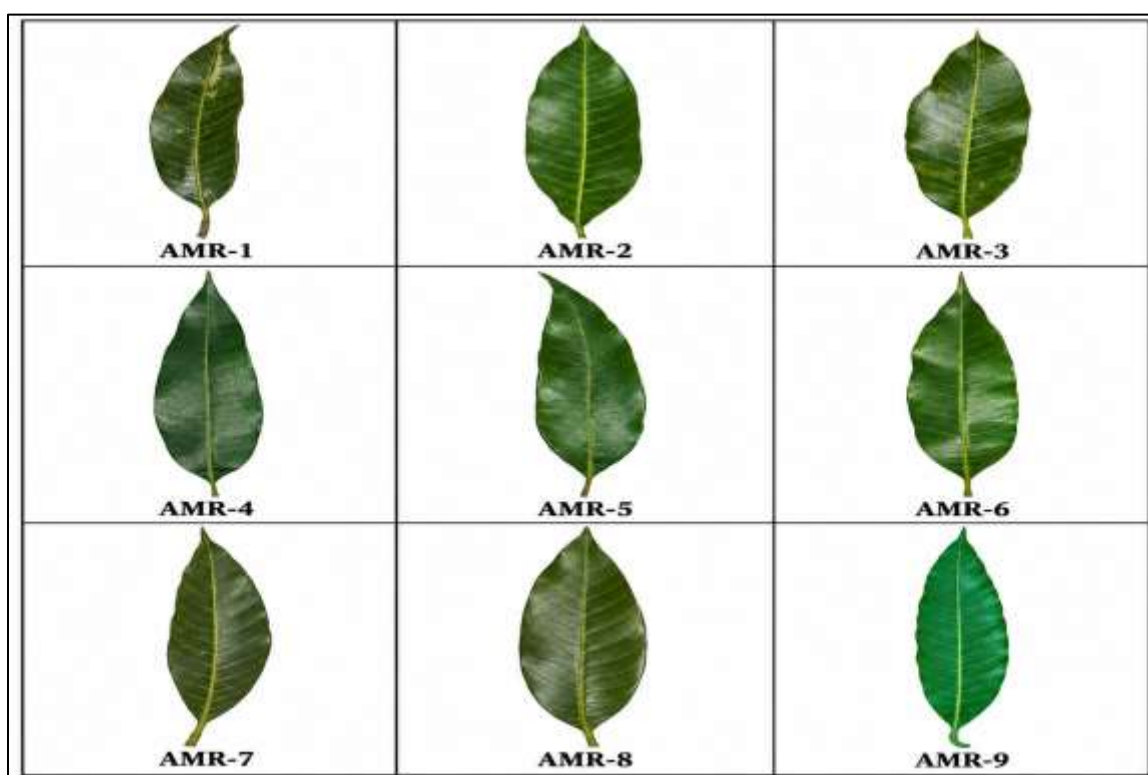


Fig. 3. Representative mature leaves of mango genotypes AMR-1 to AMR-9 arranged in genotype order.

The low number of variable leaf states does not make leaf characters uninformative. A character that is uniform within this small set can still be useful when AMR material is compared with a wider collection, and combinations of blade shape, apex, base and margin can aid field identification. Within the present collection, however, leaf descriptors alone would distinguish only AMR-3 by blade shape and AMR-9 by margin. The remaining seven genotypes shared the same four-state profile of lanceolate blade, acuminate apex, acute base and entire margin. This result shows why genotype identification should not depend on a single leaf descriptor.

Mature-leaf characters are generally easier to standardize than juvenile-leaf colour because they can be sampled over a longer period, but leaf position, age, damage and dehydration can still alter apparent outline. The sampling protocol used multiple healthy mature leaves from several canopy positions, whereas Fig. 3 shows only one representative leaf per genotype. The table therefore remains the primary record. Regional mango studies have likewise used combinations of leaf and fruit morphology, rather than a single photographed leaf, to discriminate landraces (Sennhenn et al. 2014; Kyaing et al. 2019).

Fruit morphology

Fruit morphology showed the largest number of descriptor combinations (Table 4) (Fig. 4). All five named fruit-shape states were represented. Elliptic fruit occurred in AMR-1, AMR-2 and AMR-5 and was the most frequent state (33.3%). AMR-3 and AMR-4 were obovoid, and AMR-6 and AMR-8 were ovoid (22.2% for each state). AMR-7 was roundish and AMR-9 was oblong (11.1% for each state). The distribution across all five states, rather than dominance by one outline, accounts for much of the visible diversity in the fruit plate.

Fruit apex added information that was not completely determined by overall shape. AMR-9 had the only acute apex (11.1%). Obtuse apices occurred in AMR-2, AMR-3, AMR-5 and AMR-8 (44.4%), and round apices occurred in AMR-1, AMR-4, AMR-6 and AMR-7 (44.4%). The two obovoid genotypes, for example, differed in apex state: AMR-3 was obtuse and AMR-4 was round. Likewise, the elliptic group contained one round-apex genotype and two obtuse-apex genotypes. Recording both characters therefore avoids collapsing visibly different fruits into one shape class.

Green was the most frequent ripe skin-colour state and was recorded in AMR-2, AMR-3, AMR-4, AMR-7, AMR-8 and AMR-9 (66.7%). AMR-1 and AMR-6 were greenish yellow (22.2%), and AMR-5 was yellow (11.1%). No genotype showed the red-blush or purple-patch states included in descriptor 7.4.22. Colour must be interpreted at the specified ripening stage because harvest maturity, illumination and camera processing can change its visual appearance. The coded observations, rather than pixel colour in the assembled plate, were therefore used for the frequency calculation.

Lenticel density was medium in AMR-1, AMR-2, AMR-5 and AMR-9 and dense in AMR-3, AMR-4, AMR-6 and AMR-7; each state represented 44.4% of the collection. AMR-8 alone had sparse lenticels (11.1%). A shallow fruit-

stalk cavity occurred in seven genotypes (77.8%), while the cavity was absent in AMR-8 and AMR-9 (22.2%). Neck prominence was slightly prominent in AMR-1, AMR-2, AMR-4, AMR-6 and AMR-9 (55.6%) and absent in AMR-3, AMR-5, AMR-7 and AMR-8 (44.4%). No medium-to-very-deep stalk cavity or prominent-to-very-prominent neck was recorded.

Table 4. External fruit morphological descriptor states of mango genotypes AMR-1 to AMR-9.

Genotype	Fruit shape (7.4.7)	Apex (7.4.8)	Ripe skin colour (7.4.22)	Lenticels (7.4.13)	Stalk cavity (7.4.15)	Neck (7.4.17)
AMR-1	2	3	2	5	1	1
AMR-2	2	2	1	5	1	1
AMR-3	5	2	1	7	1	0
AMR-4	5	3	1	7	1	1
AMR-5	2	2	3	5	1	0
AMR-6	4	3	2	7	1	1
AMR-7	3	3	1	7	1	0
AMR-8	4	2	1	3	0	0
AMR-9	1	1	1	5	0	1

Note: Fruit shape: 1 = oblong, 2 = elliptic, 3 = roundish, 4 = ovoid, 5 = obovoid, 99 = other. Apex: 1 = acute, 2 = obtuse, 3 = round, 99 = other. Ripe skin colour: 1 = green, 2 = greenish yellow, 3 = yellow, 4 = green with red blush, 5 = green with purple patches. Lenticel density: 3 = sparse, 5 = medium, 7 = dense. Stalk cavity: 0 = absent, 1 = shallow, 2 = medium, 3 = deep, 4 = very deep. Neck prominence: 0 = absent, 1 = slightly prominent, 2 = prominent, 3 = very prominent.

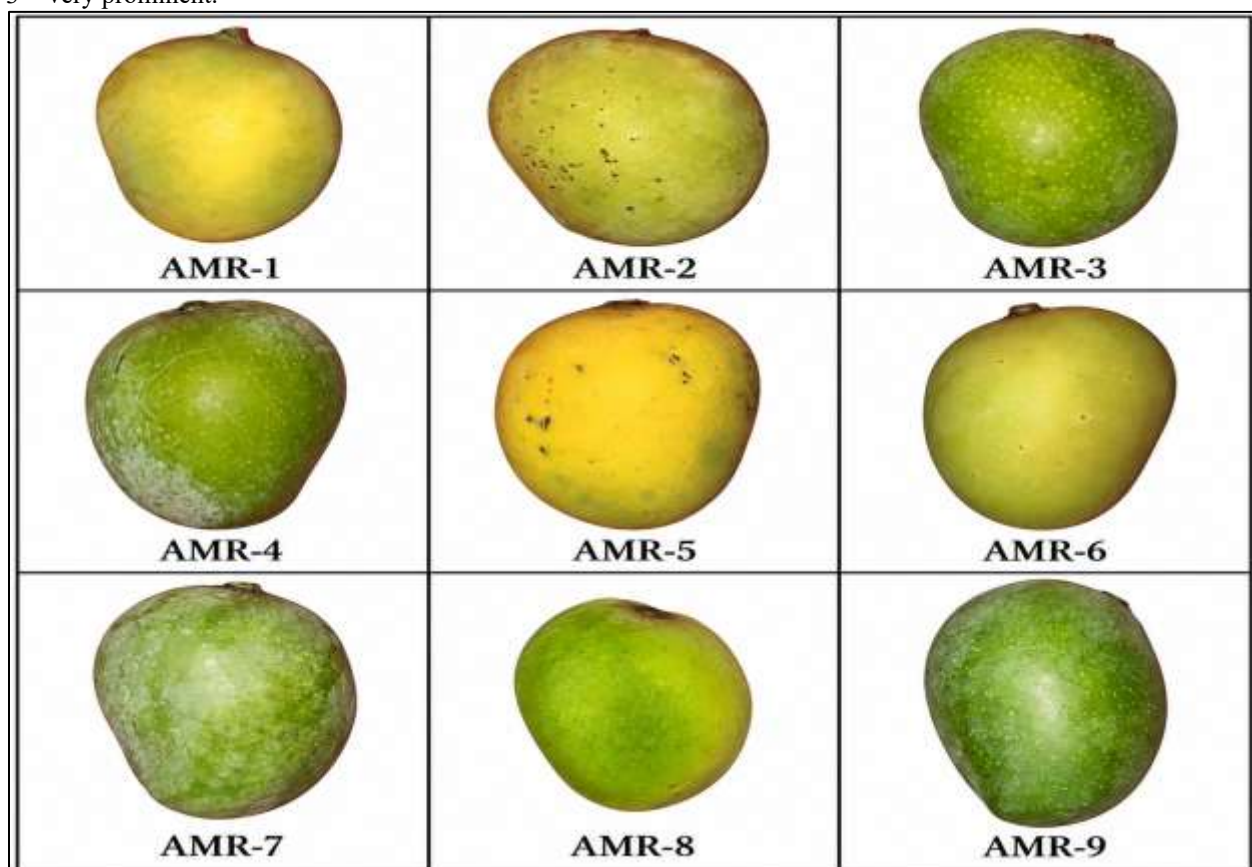


Fig. 4. Representative fruits of mango genotypes AMR-1 to AMR-9 arranged in genotype order.

The combined states produced a distinct external profile for each genotype. AMR-1 was elliptic with a round apex, greenish-yellow skin, medium lenticels, a shallow cavity and a slightly prominent neck. AMR-2 shared the elliptic outline but differed in its obtuse apex and green skin. AMR-3 and AMR-4 were both obovoid with green skin and dense lenticels, yet they differed in apex and neck states. AMR-5 combined elliptic shape, an obtuse apex and the only yellow skin colour. AMR-6 was ovoid with a round apex and greenish-yellow skin; AMR-7 combined a roundish outline with a round apex; AMR-8 was ovoid and was the only genotype with sparse lenticels; and AMR-9 combined

an oblong outline with the only acute apex. These combinations are more informative for documentation than any single frequency.

The greater differentiation in fruit than leaf traits agrees with the broad fruit variation reported in geographically diverse mango collections (Rajan et al. 2013; Zhang et al. 2020; Singh et al. 2025). Fruit characters are directly relevant to recognition and farmer selection, but external appearance alone cannot establish eating quality, processing suitability or yield potential. Pulp colour and texture, soluble solids, acidity, fibre, stone proportion and aroma were outside the present dataset. Claims that any AMR genotype is superior for cultivation would therefore be premature.

Table 5. Summary of morphological descriptor frequencies among the nine AMR mango genotypes.

Descriptor	Observed states (number)	Most frequent state	Genotypes, n (%)
Crown shape	5	Semi-circular	4 (44.4)
Growth habit	2	Spreading	7 (77.8)
Foliage density	2	Intermediate	5 (55.6)
Leaf blade shape	2	Lanceolate	8 (88.9)
Leaf apex	1	Acuminate	9 (100.0)
Leaf base	1	Acute	9 (100.0)
Leaf margin	2	Entire	8 (88.9)
Fruit shape	5	Elliptic	3 (33.3)
Fruit apex	3	Obtuse and round	4 each (44.4)
Ripe skin colour	3	Green	6 (66.7)
Lenticel density	3	Medium and dense	4 each (44.4)
Stalk cavity	2	Shallow	7 (77.8)
Neck prominence	2	Slightly prominent	5 (55.6)

DISCUSSION

Across the three morphological groups, fruit descriptors supplied the highest number of variable states, crown shape provided additional separation, and leaf morphology was comparatively conserved. AMR-3 and AMR-9 were the only erect trees and also carried the two uncommon leaf states: elliptic blade in AMR-3 and wavy margin in AMR-9. AMR-9 was particularly recognizable because its tree, leaf margin, fruit shape and fruit apex each included a less frequent state. Such a combination can be used to prioritize the tree for propagation and repeated study, but rarity within nine genotypes is not evidence of agronomic value or population-level rarity.

The results provide a traceable baseline for genotype management. The AMR identifiers, coordinates, descriptor codes and photographic plates can help prevent label confusion during future collection and propagation. They can also guide selection of contrasting material for common-garden trials. Pairing phenotypically distinct genotypes in subsequent analyses may improve the efficiency of biochemical screening or molecular diversity work, but the descriptor profiles should remain linked to voucher photographs and collection-site records.

The nine AMR genotypes showed documented differences in qualitative tree, leaf and external fruit descriptors. Spreading growth habit and intermediate foliage density were most frequent among the sampled trees, lanceolate leaves predominated, and fruit shape supplied the greatest visible differentiation. AMR-3, AMR-5, AMR-8 and AMR-9 carried useful contrasting combinations for further study. The records support conservation and accurate genotype tracking, while conclusions about genetic distinctness, yield, quality or adaptation require replicated multi-season and molecular evaluation.

CONCLUSION

The nine indigenous mango genotypes showed clear variation in tree, leaf and especially fruit morphological traits under sodic soil conditions of Ayodhya. Fruit characters provided the greatest discrimination, with AMR-3, AMR-5, AMR-8 and AMR-9 showing particularly distinctive trait combinations. The study provides a useful baseline for germplasm conservation and genotype identification.

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AUTHORSHIP CONTRIBUTION STATEMENT

Jagveer Singh, Santosh Kumar Verma, Atul Yadav designed the study. Rishabh, Hemant Kumar, Amit Mishra; field investigation: Rishant Shukla, Satyanshu Singh; descriptor scoring and data curation: Ujjwal Shrivastava, Imran Ali, Aman Kumar

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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DATA AVAILABILITY

The descriptor dataset and supporting photographs are available from the corresponding author on reasonable request.

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